Clinical research article

Antibiotic pharmacotherapy of pleurisy, pleural empyema, infections of various genesis: ABC and VED analysis

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SUMMARY

Introduction: Antibiotic resistance remains one of the greatest challenges in global health, which necessitates a systemic approach to the rational use of antimicrobial medicines, in particular in patients with infections of various genesis, pleurisy, pleural empyema, tuberculosis and chronic infections. In Latin American countries, in particular in Colombia, the problem of uncontrolled antibiotic use is combined with socio-economic factors that affect access to effective pharmacotherapy, especially in patients with pleurisy, pleural empyema, tuberculosis and chronic infections. **Objective:** To conduct an analysis of antimicrobial medicines registered in Colombia using ABC and VED analysis, to identify priority active substances for further planning of procurement, consumption control strategies, and prescription in the treatment of pleurisy, pleural empyema, tuberculosis and chronic infections. **Methodology:** The study was based on the analysis of 20 antibacterial drugs registered in Colombia, using international databases, price catalogs, and WHO guidelines. An ABC analysis was performed by cost level, ranking by criticality criterion (VED), and the share of each drug in total costs was calculated. Additionally, literature sources on antimicrobial resistance. **Results:** The highest share in costs (category A) was made by Ceftriaxone, Amoxicillin/clavulanic acid, and Azithromycin. Within category B, Ciprofloxacin, Doxycycline, and Cefalexin were identified. Category C drugs had a small share of costs, but a high frequency of use. The relationship between price indicators and prevalence of use indicates the need to optimize procurement policies. **Discussion:** The data obtained emphasize the need to implement antimicrobial stewardship strategies and national monitoring. **Conclusions:** The results of the study have practical

value for health policy, antimicrobial control and the formation of national protocols for the treatment of pleurisy, pleural empyema, tuberculosis and chronic infections. ABC/VED analysis allows to identify critical points in the costs of antibiotics, outlines the prospects for the development of individualized pharmacotherapy in the context of increasing antibiotic resistance.

Keywords: pharmacotherapy; antimicrobial medicines; pleurisy; pleural empyema; tuberculosis; chronic infections; ABC analysis; VED analysis; infections.

RESUMEN

Farmacoterapia antibiótica de la pleuresía, el empiema pleural y las infecciones de diversa etiología: análisis ABC y VED

Introducción: La resistencia a los antibióticos sigue siendo uno de los mayores desafíos para la salud mundial, lo que exige un enfoque sistémico para el uso racional de los medicamentos antimicrobianos, en particular en pacientes con infecciones de diversa etiología, pleuresía, empiema pleural, tuberculosis e infecciones crónicas. En los países latinoamericanos, especialmente en Colombia, el problema del uso incontrolado de antibióticos se combina con factores socioeconómicos que afectan el acceso a una farmacoterapia eficaz, sobre todo en pacientes con pleuresía, empiema pleural, tuberculosis e infecciones crónicas. **Objetivo:** Realizar un análisis de los medicamentos antimicrobianos registrados en Colombia mediante el análisis ABC y VED, para identificar los principios activos prioritarios para la planificación de la adquisición, las estrategias de control del consumo y la prescripción en el tratamiento de la pleuresía, el empiema pleural, la tuberculosis y las infecciones crónicas. **Metodología:** El estudio se basó en el análisis de 20 medicamentos antibacterianos registrados en Colombia, utilizando bases de datos internacionales, catálogos de precios y las guías de la OMS. Se realizó un análisis ABC por nivel de costo, clasificación según el criterio de criticidad (VED) y se calculó la proporción de cada fármaco en el costo total. Adicionalmente, se consultaron fuentes bibliográficas sobre resistencia antimicrobiana. **Resultados:** La mayor proporción en los costos (categoría A) correspondió a ceftriaxona, amoxicilina/ácido clavulánico y azitromicina. Dentro de la categoría B, se identificaron ciprofloxacino, doxiciclina y cefalexina. Los fármacos de categoría C representaron una pequeña proporción de los costos, pero una alta frecuencia de uso. La relación entre los indicadores de precio y la prevalencia de uso señala la necesidad de optimizar las políticas de adquisición. **Discusión:** Los datos obtenidos enfatizan la necesidad de implementar estrategias de administración de antimicrobianos y monitoreo nacional. **Conclusiones:** Los resultados del estudio tienen valor práctico para la política sanitaria, el control antimicrobiano y la formulación de protocolos nacionales para el tratamiento de la pleuresía, el empiema pleural, la tuberculosis y las infecciones crónicas. El análisis ABC/VED permite identificar puntos críticos en los costos de los antibióticos y perfila las perspectivas para el desarrollo de farmacoterapia individualizada en el contexto de la creciente resistencia a los antibióticos.

Palabras clave: farmacoterapia; medicamentos antimicrobianos; pleuritis; empiema pleural; tuberculosis; infecciones crónicas; análisis ABC; análisis VED; infecciones.

RESUMO

Farmacoterapia antibiótica da pleurisia, empiema pleural e infecções de diversas origens: análise ABC e VED

Introdução: A resistência aos antibióticos continua sendo um dos maiores desafios da saúde global, o que exige uma abordagem sistêmica para o uso racional de medicamentos antimicrobianos, em particular em pacientes com infecções de diversas origens, pleurisia, empiema pleural, tuberculose e infecções crônicas. Nos países da América Latina, especialmente na Colômbia, o problema do uso descontrolado de antibióticos se combina com fatores socioeconômicos que afetam o acesso à farmacoterapia eficaz, principalmente em pacientes com pleurisia, empiema pleural, tuberculose e

infecções crônicas. **Objetivo:** Realizar uma análise dos medicamentos antimicrobianos registrados na Colômbia utilizando as análises ABC e VED, para identificar as substâncias ativas prioritárias para o planejamento de aquisição, estratégias de controle de consumo e prescrição no tratamento da pleurisia, empiema pleural, tuberculose e infecções crônicas. **Metodologia:** O estudo baseou-se na análise de 20 medicamentos antibacterianos registrados na Colômbia, utilizando bases de dados internacionais, tabelas de preços e diretrizes da OMS. Foi realizada uma análise ABC por nível de custo, classificando-se pelo critério de criticidade (VED), e calculou-se a participação de cada medicamento nos custos totais. Adicionalmente, foram consultadas fontes bibliográficas sobre resistência antimicrobiana. **Resultados:** A maior participação nos custos (categoria A) foi atribuída à ceftriaxona, amoxicilina/ácido clavulânico e azitromicina. Na categoria B, foram identificados ciprofloxacino, doxiciclina e cefalexina. Os medicamentos da categoria C apresentaram uma pequena participação nos custos, mas alta frequência de uso. A relação entre os indicadores de preço e a prevalência de uso indica a necessidade de otimizar as políticas de aquisição. **Discussão:** Os dados obtidos enfatizam a necessidade de implementar estratégias de gestão de antimicrobianos e monitoramento nacional. **Conclusões:** Os resultados do estudo têm valor prático para políticas de saúde, controle antimicrobiano e formulação de protocolos nacionais para o tratamento de pleurisia, empiema pleural, tuberculose e infecções crônicas. A análise ABC/VED permite identificar pontos críticos nos custos dos antibióticos, delineando as perspectivas para o desenvolvimento de farmacoterapia individualizada no contexto do aumento da resistência antimicrobiana.

Palavras-chave: farmacoterapia; medicamentos antimicrobianos; pleurite; empiema pleural; tuberculose; infecções crônicas; análise ABC; análise VED; infecções.

1. INTRODUCTION

Rational consumption of antimicrobial medicines is a critically important factor in ensuring the effectiveness of pharmacotherapy, preventing antibiotic resistance and optimizing healthcare costs [1, 2].

The increasing prevalence of infectious diseases, comorbid conditions in patients of different age groups, as well as the threat of global antimicrobial resistance require a systematic review of approaches to the selection of antibiotics for pharmacotherapy of infectious, pulmonological, gastroenterological, urological, otolaryngological and other diseases [3-5]. Infections of various genesis are gaining particular attention against the background of Covid, post-Covid, long-Covid disorders [6-10].

One of the key approaches to streamlining antibacterial pharmacotherapy is the use of analysis methods: ABC (Always, Better, Control) – analysis by cost priority and VED (Vital, Essential, Desirable) – classification by degree of clinical significance: vital, necessary and secondary drugs [11-13].

ABC analysis allows you to classify antibiotics by the amount of costs incurred by each of them. Accordingly, it is possible to determine antimicrobial medicines with the greatest economic impact on the health care system budget. In turn, VED analysis allows you to divide antibiotics by the criticality of their clinical significance: into vital (Vital), necessary (Essential) and desirable (Desirable). The combined use of both analysis methods provides the opportunity to form an effective strategy for purchasing, logistics and use of antibiotics in medical practice, especially in patients with pleurisy, pleural empyema, tuberculosis and chronic infections.

Particular attention within the framework of rationalization of antibiotic therapy should be paid to international non-proprietary names. International non-proprietary names are the basis for harmonization of drug formulas, formation of national lists of essential medicines

and implementation of evidence-based international clinical protocols. In the conditions of dynamic development of the global pharmaceutical market, studying the range of antibiotics by international non-proprietary names in drug registries of different countries, in particular Colombia, is gaining strategic importance [14].

Colombia, which in recent years has been actively harmonizing its regulatory framework in the field of health care in accordance with international standards, demonstrates an example of openness of the pharmaceutical market to international manufacturers from the United States of America, European Union countries, Turkey, Canada, etc.

Clinical-pharmacological analysis of antimicrobial medicines registered in Colombia, which meet international standards and clinical protocols, allows us to determine the degree of availability of key antibiotics, as well as to build a predictive model of the costs of treating infectious diseases of various genesis, especially in patients with pleurisy, pleural empyema, tuberculosis and chronic infections [15].

In the context of the strategic trend towards increasing the evidence base and economic feasibility of medical interventions, the results of the ABC/VED analysis can become the basis for the formation of national antimicrobial medicines formularies, clinical patient itineraries, as well as strategic planning of antibiotic procurement and logistics within state and insurance programs.

The relevance of such a study is also due to the need to ensure transparency of the pharmaceutical market in the context of global challenges associated with changes in logistics chains, strengthening regulatory control, the need to make economically sound decisions when purchasing, increasing the availability of antibiotics for patients with infectious diseases of various genesis, pleurisy, pleural empyema, tuberculosis.

The focus of the authors' study was on antimicrobial medicines registered in Colombia. Research on the Colombian market, as a country with a high level of imports of finished dosage forms and a transparent regulatory environment, may be useful for further studying the availability of clinical and pharmacological groups of drugs for patients with health disorders according to the International Classification of Diseases, 11th revision [16-18].

In this context, research into the implementation of a comprehensive ABC/VED analysis of antimicrobial medicines registered in Colombia, taking into account international clinical recommendations and standards, is relevant and necessary.

The purpose of this study is to conduct an analysis of antimicrobial medicines for the pharmacotherapy of patients registered in Colombia, taking into account international clinical protocols and evidence-based recommendations. The study involves the use of assessment methods, in particular ABC analysis (analysis of drug costs) and VED analysis (classification by degree of clinical significance: vital, necessary and minor drugs), to identify priority international generic names of antibiotics and assess their availability on the Colombian pharmaceutical market.

The proposed approach aims to contribute to the formation of sound strategies for the use of antibiotics in clinical practice, improving the structure of pharmaceutical supply and improving regulatory policies in the field of circulation of antimicrobial medicines.

2. METHODOLOGY

The study was conducted in several consecutive stages using a comprehensive approach to marketing analysis of antimicrobial medicines registered in Colombia [19].

Particular attention was paid to the analysis of international non-proprietary names, trade names, dosages, release forms, manufacturing countries and price indicators in US dollars antimicrobial medicines. The study uses international recommended names of antibiotics registered in open registries. The collected data can be adapted for the pharmaceutical markets of Colombia and Latin American countries.

2.1. Selection of active substances (international non-proprietary names): The basic source for forming the list of antibiotics recommended for analysis was the guideline based on the principles of evidence-based medicine created by DUODECIM Medical Publications, Ltd. [20]. The guideline is harmonized with international pharmacotherapy protocols for the treatment of infections of various genesis. From it, international non-proprietary names were selected that correspond to modern international protocols and cover the main groups of systemic antibacterial agents (penicillin, cephalosporins, macrolides, fluoroquinolones, tetracyclines, carbapenems, etc.).

2.2. Verification of drugs in the Colombian registry: To determine the availability of specific antimicrobial medicines by international non-proprietary names, a search was carried out in the Colombian state registry of medicines, published on the website of the Agency for the Regulation of Medical Activities of the Ministry of Health of Colombia [21]. Only those drugs that had a valid registration status at the time of analysis, contained the corresponding international non-proprietary names in their composition, and were intended for systemic use in adults were taken into account.

2.3. Estimation of the cost of drugs: Retail prices of antimicrobial medicines were determined according to data from open pharmaceutical resources, electronic pharmacies in Colombia, as well as international sites that support online cost monitoring. To unify the currency indicator, all prices were converted into US dollars (USD) at the average official exchange rate on the date of the study – 1 USD = XX.XX GEL (as of May 1, 2025 according to the National Bank of Colombia).

2.4. ABC analysis: The standard ABC analysis methodology was applied: *i*) Category A – Antimicrobial medicines with the highest level of costs (over 70% of total costs); *ii*) Category B – Antimicrobial medicines with an average level of costs (15–20%); *iii*) Category C – Antimicrobial medicines with the lowest costs (up to 10%).

The calculation was carried out by ranking the total cost of drug packages in descending order and calculating their share in the total cost structure.

2.5. VED analysis: Antibiotics were divided into three categories based on the international evidence base according to the criteria of clinical significance: *i*) Vital (V) – vital; *ii*) Essential (E) – essential; *iii*) Desirable (D) – secondary. The classification was carried out taking into account the data of the World Health Organization.

2.6. Combined ABC/VED analysis: After performing both methods, a combined ABC/VED matrix was created, which allows to identify the most priority antimicrobial medicines that require priority funding and supply in medical institutions.

2.7. Data processing: All collected data were summarized in tables, diagrams and structured in accordance with international approaches to evaluation. Statistical processing was carried

out using descriptive statistics methods: average values, percentage distribution, and share of costs in each category.

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3. RESULTS AND DISCUSSION

The analysis involved a systematization of the international non-proprietary names of antimicrobial medicines registered in Colombia according to their affiliation with clinical and pharmacological groups that correspond to modern approaches to the classification of antibiotics according to the international nomenclature. For this purpose, data from the official list of medicines approved by the World Health Organization were used, in particular the Model List of Essential Medicines (twenty-third edition, 2023), as well as WHO recommendations for the classification of antibiotics according to the AWaRe (Access, Watch, Reserve) approach – this is an international classification system for antibacterial drugs developed by the World Health Organization (WHO) to: optimize the use of antibiotics, prevent antimicrobial resistance, and facilitate the formation of national lists of essential medicines [22]. The distribution of active substances was carried out taking into account the mechanism of action, spectrum of activity, chemical structure, and recommendations for prescribing for various nosologies in patients. Each international non-proprietary name was analyzed for its belonging to a specific clinical-pharmacological group, with subsequent verification of its presence in the Colombian drug registry and its recommendation for use in clinical practice, in particular in patients with pleurisy, pleural empyema, tuberculosis and chronic infections [16, 23].

The generalized results of this stage of the study are presented in Table 1, which presents the international non-proprietary names of antibiotics that were included in the sample, indicating their clinical-pharmacological affiliation. This distribution is the basis for further economic and strategic analysis of antimicrobial medicines, and also allows us to outline the logic of choosing drugs for inclusion in the pharmaceutical supply system of antimicrobial medicines within the guaranteed package of medical services.

Table 1. Distribution of Antimicrobial medicines by clinical-pharmacological groups

Clinical and pharmacological group	**International non-proprietary names**
Penicillins	Amoxicillin; Amoxicillin/Clavulanic acid; Ampicillin; Cloxacillin; Benzylpenicillin; Phenoxymethylpenicillin
Cephalosporins	Cefalexin; Cefazolin
Macrolides/lincosamides	Azithromycin; Clindamycin
Fluoroquinolones	Ciprofloxacin
Aminoglycosides	Gentamicin; Amikacin
Tetracyclines	Doxycycline
Others	Chloramphenicol; Metronidazole; Sulfamethoxazole/Trimethoprim; Nitrofurantoin

The next stage of the study was to assess the presence of selected international non-proprietary names of antimicrobial medicines on the Colombian pharmaceutical market in terms of their production origin, release forms and compliance with clinical recommendations. The applied approach made it possible to carry out a systematic inventory of antimicrobial medicines registered in the country, as well as to determine key marketing and economic characteristics.

All international non-proprietary names of antibiotics registered in Colombia, selected for analysis, comply with current international protocols for antibacterial therapy, covering infections of varying severity – from mild forms in outpatient practice to life-threatening conditions requiring inpatient treatment with the use of reserve antibiotics [24, 25].

Analysis of data from the State Register of Medicines of Colombia showed that the specified antimicrobial medicines are represented mainly by imported products. The main producing countries are the United States of America, the countries of the European Union (in particular France, Germany, Slovakia, Poland), as well as Turkey and Canada. This distribution indicates a high level of circulation of imported antibiotics in the Colombian pharmaceutical market.

The identified dosage forms of antimicrobial medicines are diverse and include both oral preparations (tablets, capsules) and forms for parenteral administration, which is fundamentally important for the treatment of severe conditions. The study also recorded the presence of oral suspensions, which are traditionally associated with pediatric practice, but are also used in adults in case of swallowing difficulties. Some Antimicrobial medicines are presented in special forms - for example, modified-release capsules or powders for injection, which meets the requirements of modern antibiotic therapy.

The average cost of a package of drugs was estimated from open sources of online pharmacies, where the approximate retail price per package in US dollars was recorded at the rate of the National Bank of Colombia. For comparison, prices of international analogues from the US and European Union markets, obtained from the resources of SingleCare and PharmacyChecker, were also used, which made it possible to carry out the cost positioning of each drug in a global context [26, 27].

A generalized characteristic of the antimicrobial medicines included in the sample, indicating international non-proprietary names, trade names, and manufacturing countries, is given in Table 2, and information on dosages, release forms, and price indicators is given in Table 3. It is the basis for further analysis of the cost structure (ABC analysis) and clinical priority (VED analysis).

Table 2. General characteristic of the studied Antimicrobial medicines

No.	International non-proprietary names	Trade name	Country of origin
1.	Amoxicillin	Amoxil	Slovakia
2.	Amoxicillin/Clavulanic acid	Augmentin	France
3.	Benzylpenicillin sodium	Crystalline Penicillin	Turkey
4.	Cefalexin	Keflex	Poland
5.	Cefazolin	Zolicef	Italy
6.	Ceftriaxone	Rocephin	Switzerland
7.	Ciprofloxacin	Ciprobay	Germany
8.	Azithromycin	Azitro	Turkey
9.	Clindamycin	Dalacin C	Canada
10.	Doxycycline	Doxal	Bulgaria
11.	Gentamicin	Gentamin	Turkey

12.	Amikacin	Amikacine	India
13.	Metronidazole	Flagyl	France
14.	Nitrofurantoin	Furadonin	Bulgaria
15.	Sulfamethoxazole/Trimethoprim	Biseptol	Poland
16.	Phenoxymethylpenicillin	Ospen	Austria
17.	Procaine benzylpenicillin	Penbex	Turkey
18.	Chloramphenicol	Levomycetin	Czech Republic
19.	Ampicillin	Ampibact	Hungary
20.	Cloxacillin	Cloxin	India

Table 3. Dosage, dosage forms and price indicators of the studied Antimicrobial medicines

No.	International non-proprietary names	Dosage	Release form	Price per package (USD)
1.	Amoxicillin	500 mg	Tablets	6.80
2.	Amoxicillin/Clavulanic acid	875 mg /125 mg	Tablets	14.50
3.	Benzylpenicillin sodium	1,000,000 IU	Powder for injection	5.90
4.	Cefalexin	500 mg	Capsules	5.00
5.	Cefazolin	1 g	Powder for injection	7.80
6.	Ceftriaxone	1 g	Powder for injection	16.00
7.	Ciprofloxacin	500 mg	Tablets	6.80
8.	Azithromycin	500 mg	Tablets	7.00
9.	Clindamycin	300 mg	Capsules	10.20
10.	Doxycycline	100 mg	Tablets	4.50
11.	Gentamicin	80 mg/2 ml	Ampoules	5.40
12.	Amikacin	500 mg/2 ml	Ampoules	6.10
13.	Metronidazole	250 mg	Tablets	3.00
14.	Nitrofurantoin	100 mg	Tablets	2.50
15.	Sulfamethoxazole/Trimethoprim	400 mg/80 mg	Tablets	2.20
16.	Phenoxymethylpenicillin	1,000,000 IU	Tablets	5.70
17.	Procaine benzylpenicillin	600,000 IU	Suspension for injection	9.30
18.	Chloramphenicol	250 mg	Tablets	3.10
19.	Ampicillin	500 mg	Capsules	4.40
20.	Cloxacillin	500 mg	Capsules	4.90

The presented tables 2 and 3 summarize the key characteristics of the antimicrobial medicines that were included in the analysis. The sample included international non-proprietary names that have a valid registration in the territory of Colombia as of June 2025. When selecting drugs, the presence in the state register of medicines, commercial presence in the pharmaceutical market, compliance with international clinical recommendations, as well as the representativeness of pharmacological groups were taken into account.

All antimicrobial medicines presented in table 2 have a confirmed manufacturing origin from international pharmaceutical companies, in particular from the European Union, the USA, Turkey, Canada, Slovakia and Poland. The sample includes both oral forms (tablets, capsules) and injectables and powders for the preparation of solutions, which allows taking into account different clinical scenarios of use in adult patients, including outpatient and inpatient practice [28].

The weighted average cost analysis revealed that the cost of a package of oral antibiotics on the Colombian pharmaceutical market (approximately 7 US dollars) is generally in line

with world indicators. In contrast, parenteral drugs have a significantly higher cost, which should be taken into account when conducting ABC/VED analysis as an economically significant factor.

Thus, tables 2 and 3 illustrate a reasonable and representative selection of antimicrobial medicines for further analysis. It reflects the clinical-pharmacological, marketing, and cost characteristics of the use of antibiotics in adult patients.

One of the main methods of assessment of cost-effectiveness in pharmaceutical provision is ABC analysis. It allows you to identify antimicrobial medicines that consume the largest share of financial resources allocated for antibacterial therapy and rank them by level of economic significance. Within the framework of the study, ABC analysis was used to assess the cost structure of antibiotics registered in Colombia and recommended for medical use.

The calculation of the cost share was based on the average retail price of each drug package in US dollars. Prices were obtained from open sources of online pharmacy resources, relevant at the time of data collection. This approach allowed not only to identify the most costly items, but also to form a sound basis for further combining economic and clinical prioritization in the combined analysis.

For the ABC analysis, the 10 most representative international non-proprietary names (INNs) of antibacterial drugs from the general list were selected. The selection was carried out according to the criteria of frequency of prescription, demand in clinical practice, availability on the Colombian market, as well as the economic significance of the costs of the corresponding drugs. This approach allowed to focus the analysis on the most influential active substances for the health care system, without duplicating drugs that have identical pharmacological effects or are presented in different dosage forms, but with the same INN.

The summarized results of the ABC analysis of the costs of antimicrobial medicines registered in Colombia are presented in Table 4.

Table 4. ABC analysis of the costs of Antimicrobial medicines

No.	International Non-proprietary Name	Trade name	Price per package, USD	Share of total costs, %	Category
1.	Ceftriaxone inj.	Rocephin	16.00	24.2	A
2.	Amoxicillin/clavulanic acid	Augmentin	14.50	22.0	A
3.	Azithromycin	Azitro	7.00	10.6	A
4.	Ciprofloxacin	Ciprobay	6.80	10.3	A
5.	Doxycycline	Doxal	4.50	6.8	B
6.	Cefalexin	Keflex	5.00	7.6	B
7.	Clindamycin	Dalacin C	4.50	6.8	B
8.	Metronidazole	Flagyl	3.00	4.5	C
9.	Nitrofurantoin	Furadonin	2.50	3.8	C
10.	Sulfamethoxazole/Trimethoprim	Biseptol	2.20	3.3	C

The price analysis of the studied antibacterial drugs allowed us to determine the significant variability in the cost of packaging of drugs presented on the Colombian pharmaceutical market. Based on the data obtained, Figure 1 was constructed, which illustrates the price ratio (Price per package, USD) for individual names included in the study.

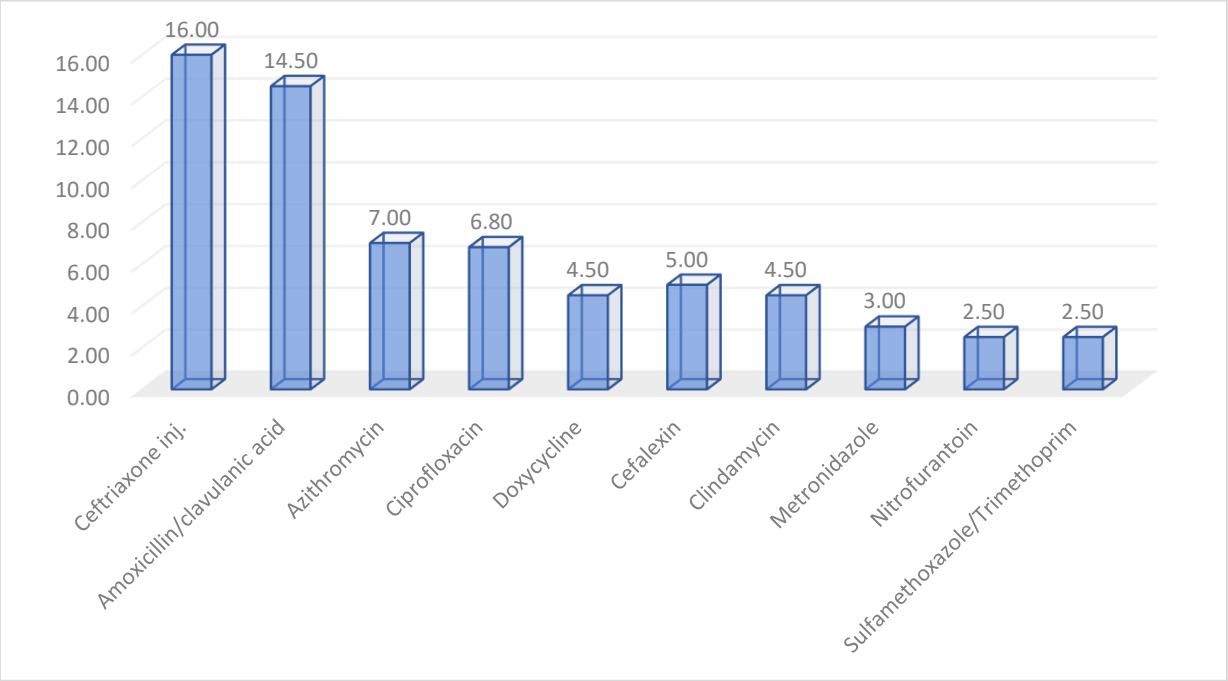

Figure 1. Price per package of antibacterial drugs, USD

The results of the analysis made it possible to divide the studied antimicrobial medicines into three categories according to the level of costs. Category A included drugs that together formed approximately 70–80 percent of the total cost of consumption. These are primarily drugs with high clinical significance and intensive use in the treatment of severe infections. In particular, these are ceftriaxone - a third-generation injectable cephalosporin, amoxicillin/clavulanic acid - a combined beta-lactam with a beta-lactamase inhibitor, azithromycin - a broad-spectrum macrolide that is often used in outpatient and inpatient practice, as well as ciprofloxacin (fluoroquinolone).

Category B includes antimicrobial medicines that provide an average share of costs (approximately 15–20 percent). It is represented by antibiotics with a high safety profile, good cost-effectiveness ratio and a wide range of indications. Among them are doxycycline (tetracycline antibiotic), cephalexin (first-generation cephalosporin) and clindamycin (drug for the treatment of anaerobic infections). These drugs are mainly used in outpatient practice for the treatment of mild to moderate infections.

Category C includes antimicrobial medicines with the lowest share in costs (up to 10 percent). These drugs are either low-cost or have limited use due to a narrow therapeutic focus or the availability of clinical alternatives. This group includes metronidazole (protozoal and antianaerobic agent), nitrofurantoin (urinary antiseptic), as well as the combination of sulfamethoxazole with trimethoprim, which has a narrowed use due to the frequency of side effects and increasing resistance.

The resulting distribution of costs is explained by a number of factors. First, injectable forms of antibiotics, such as ceftriaxone and clindamycin, are significantly more expensive compared to tablet forms, which directly affects the overall cost structure. Secondly, the predominant use of broad-spectrum first-line antibiotics (azithromycin, amoxicillin/clavulanic acid) ensures their stable presence in clinical practice, which is reflected in the high share of costs. Thirdly, drugs from category C have a less pronounced economic value due to limited or specific use.

Thus, the ABC analysis conducted allows us to draw several important conclusions. First, the core of antibacterial therapy for patients in Colombia is precisely antimicrobial medicines of category A, which have both clinical and economic priority. Second, the cost of antibiotic therapy largely depends on the form of release, namely parenteral drugs, which are significantly more expensive. Thirdly, the results of the analysis can be used for informed procurement planning and cost optimization in the system of guaranteed pharmaceutical supply.

For an in-depth assessment of the clinical significance of antimicrobial medicines, in addition to the cost characteristics, it is advisable to use VED analysis, which is based on the principles of determining the criticality of drugs in medical practice. This approach allows you to distribute antibiotics according to the degree of their necessity in providing medical care to adult patients, which is especially important for the formation of local formularies, priority purchases and stock management in hospitals.

In the framework of this study, the categorization was carried out in accordance with the list of essential medicines of the World Health Organization (twenty-third edition, 2023), as well as on the basis of the functional significance of antibiotics in modern clinical protocols [20].

The distribution of antimicrobial medicines by category was carried out taking into account their use in the treatment of life-threatening infections, the frequency of use in outpatient and inpatient practice, as well as the availability of therapeutic alternatives. Drugs that are vital and indispensable in critical conditions were classified as Vital. Antibiotics used in routine clinical practice in the treatment of the most common infections were classified as Essential. Drugs used occasionally or as a replacement for first-line drugs were classified as Desirable.

The summarized results of the VED analysis of antibiotics registered in Colombia and included in the sample are presented in Table 5. The distribution of antibiotics by VED categories is shown in Figure 2.

Table 5. Classification of antibiotics according to the results of the VED analysis

No.	International non-proprietary names	Trade name	Clinical significance	Category
1.	Ceftriaxone	Rocephin	In sepsis, meningitis, pneumonia	**V**
2.	Amoxicillin/clavulanic acid	Augmentin	In respiratory and gastrointestinal infections	**E**
3.	Azithromycin	Azitro	Alternative for allergy to β-lactams, treatment of STIs	**E**
4.	Ciprofloxacin	Ciprobay	Complicated urological and gastrointestinal infections	**E**
5.	Doxycycline	Doxal	Lyme disease, chlamydial infections, bronchitis	**E**
6.	Cefalexin	Keflex	Mild skin and respiratory tract infections	**E**
7.	Clindamycin	Dalacin C	Anaerobic infections, osteomyelitis, pneumonia in HIV-positive patients	**D**
8.	Metronidazole	Flagyl	Anaerobic infection, trichomoniasis, gardnerellosis	**E**

9.	Nitrofurantoin	Furadonin	Uroantiseptic for uncomplicated cystitis	**D**
10.	Sulfamethoxa-zole/Trime-thoprim	Biseptol	Opportunistic infections, pneumo-cystis pneumonia	**D**

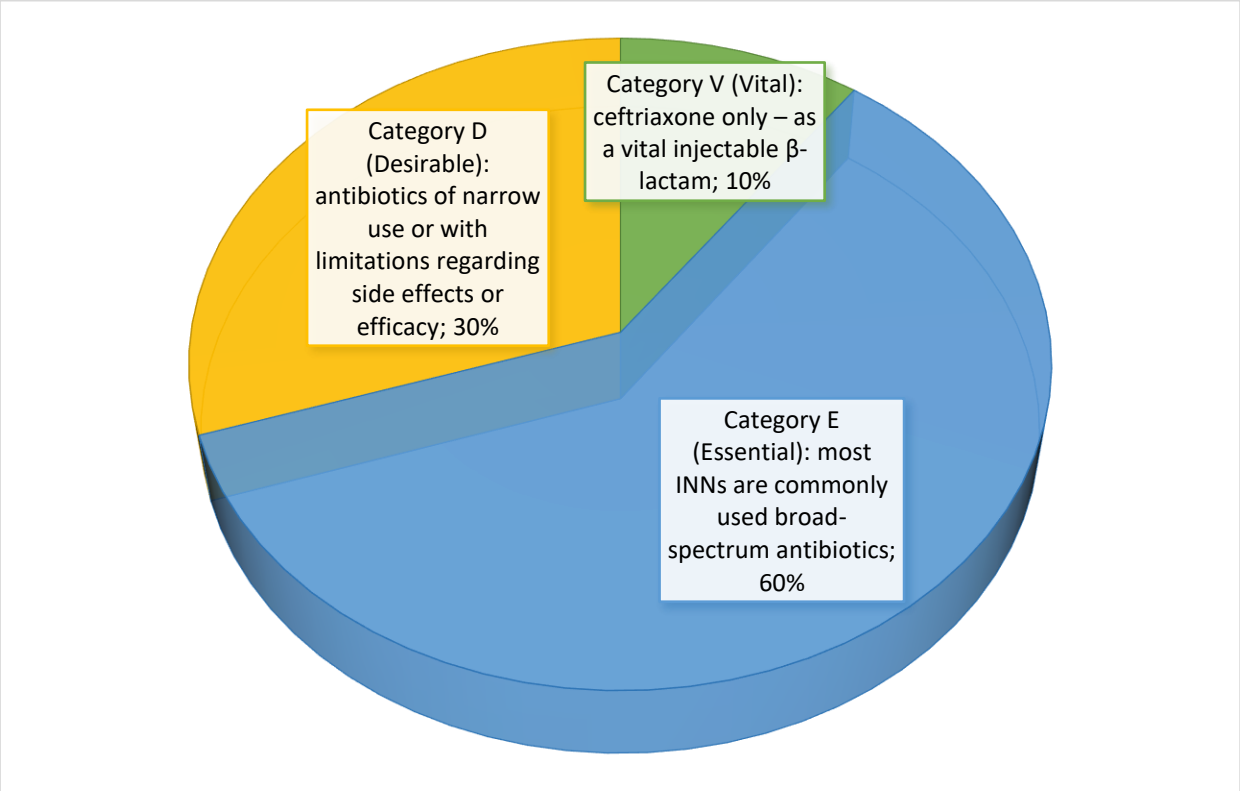

Figure 1. Distribution of antibiotics by VED categories

The justification for the distribution of antimicrobial medicines by VED analysis categories was carried out taking into account international clinical recommendations, the range of indications for use, the role of the drug in treatment regimens for infections of varying severity, as well as the potential risk of side effects.

The category of vital drugs (Vital) included ceftriaxone, which is recommended by the World Health Organization as one of the main antibiotics for the treatment of severe and life-threatening infections, such as sepsis, meningitis, hospital-acquired pneumonia, pleurisy and other complicated bacterial diseases.

The group of important drugs (Essential) included amoxicillin/clavulanic acid, ciprofloxacin and azithromycin. These antibiotics are used in the treatment of a wide range of common infections, including respiratory, urogenital and gastrointestinal, both in outpatient and inpatient medical practice. Their frequent use is due to a favorable safety profile, sufficient efficacy, and the availability of various release forms, which provides flexibility in prescribing therapy.

The category of desirable drugs (Desirable) included clindamycin, nitrofurantoin, and a combination of sulfamethoxazole and trimethoprim. These drugs are used much less frequently, have a narrow therapeutic window, or are associated with potentially serious adverse reactions, including nephrotoxicity, hypersensitivity, and cross-resistance. In addition, their use is often limited to individual clinical cases or requires special microbiological justification.

The generalized distribution showed that most of the antimicrobial medicines of the studied sample belong to the Essential category, which corresponds to modern approaches to rational antibiotic therapy of adult patients. The only drug classified as Vital was ceftriaxone, which performs a critical function in the treatment of severe bacterial infections. At the same time, Desirable drugs require justified and limited use to minimize the risk of antibiotic resistance and wasteful use of resources.

Combined ABC/VED analysis, conducted on the basis of a selected sample, is an effective tool for identifying priority medicines that require priority attention in conditions of limited health care budgets [29, 30].

This approach combines cost assessment and clinical feasibility, which allows identifying critically important antimicrobial medicines for guaranteed supply, rational formulary planning and development of procurement strategies. This technique is of particular value in conditions of risk of supply disruptions or incorrect location of resources, which directly affects the effectiveness and accessibility of pharmacotherapy, especially in patients with pleurisy, pleural empyema, tuberculosis and chronic infections.

To reconcile economic and clinical priorities, it is advisable to combine the results of ABC and VED analyses into a single analytical structure. This approach allows you to simultaneously take into account both the amount of costs incurred by each drug and its functional significance in the treatment process.

The combined ABC/VED matrix is built by cross-combining three levels of economic weight of drugs (categories A, B, C) with three levels of clinical importance (Vital, Essential, Desirable). As a result, nine analytical cells are formed, each of which reflects a specific combination of cost and clinical significance. This division allows you to identify groups of antimicrobial medicines that are of strategic importance for ensuring the health care system, as well as to determine priorities in purchasing planning, formulary formation and inventory management.

The summarized results of assigning antimicrobial medicines to the corresponding cells of the ABC/VED matrix are presented in Table 6. It shows which antibiotics combine high economic weight with critical clinical importance (segment A/V), which are costly but less important from a therapeutic point of view, and which have a small share in costs and limited clinical use.

Table 6. Distribution of antibiotics by categories of the combined ABC/VED

Category	**Vital (V)**	**Essential (E)**	**Desirable (D)**
A (high cost)	A/V – *Ceftriaxone*	A/E – *Ciprofloxacin, Amoxicillin/Clavulanate, Azithromycin*	—
B (medium)		B/E – *Doxycycline, Cefalexin*	—
C (low)	—	C/E – *Metronidazole*	C/D – *Clindamycin, Nitrofurantoin, SMX/TMP*

The share of costs in each ABC/VED segment is shown in Figure 3.

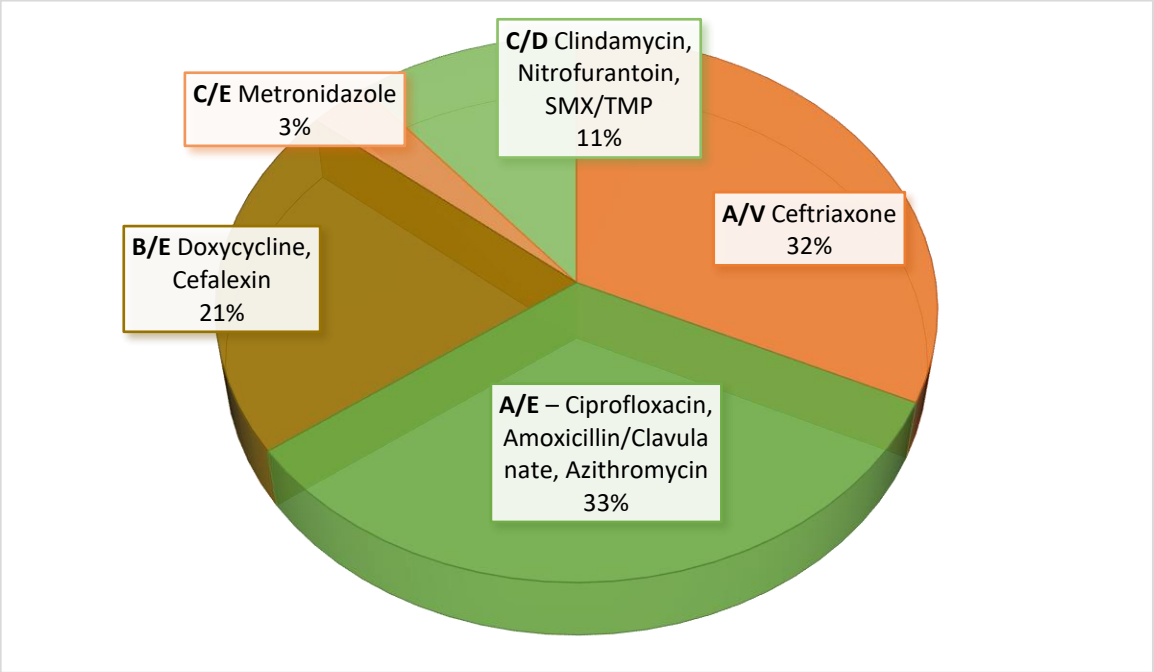

Figure 3. Share of costs in each ABC/VED segment

The overall cost structure, calculated based on the results of the combined ABC/VED analysis, covers one hundred percent of the total costs for antimicrobial medicines included in the sample (Figure 3). The highest shares of costs were recorded in the A/V and A/E zones, which indicates their extremely high clinical and economic significance. These segments reflect critical positions in antibiotic therapy of patients who require guaranteed supply and priority inclusion in formularies.

The A/V segment covers antimicrobial medicines that combine a high level of costs with a vital need in clinical practice. Ceftriaxone, a third-generation parenteral β-lactam, was included in this segment, which plays a key role in the treatment of meningitis, sepsis, severe pneumonia and other life-threatening infections. Its deficiency can cause serious clinical consequences, including fatalities, if alternative therapy cannot be used in a timely manner.

The A/E segment contains antimicrobial medicines, which have a wide range of clinical uses and are among the most expensive. In particular, amoxicillin/clavulanic acid and azithromycin are first-line drugs recommended for the treatment of respiratory infections, gastrointestinal tract infections, upper respiratory tract infections, and other nosologies common in everyday clinical practice. Their stable presence in the treatment process determines the need for guaranteed supply of these drugs in medical and pharmacy institutions.

In turn, the C/D segment combines drugs with the lowest cost indicators and limited clinical use. It includes drugs that are used episodically or as an alternative if first-line drugs are not available. Given the low level of clinical significance, the inclusion of such medicines in the basic formularies and their provision in large volumes requires additional justification and review.

The analysis confirmed that the combination of economic feasibility and clinical significance is key to the formation of an effective drug management system. Combined ABC/VED analysis allows not only to identify priority antimicrobial medicines, but also provides the opportunity to make informed management decisions within the framework of budget planning. It is a tool for optimizing resources, avoiding overspending on insignificant items, as well as for predicting the risks of shortages of drugs of strategic importance.

Thus, ceftriaxone, as a representative of the A/V segment, should be considered as a drug of the highest priority within the framework of centralized procurement and uninterrupted supply. Amoxicillin/clavulanic acid and azithromycin (segment A/E) should be maintained in stable access in health facilities due to their significant share of costs and wide clinical use. On the other hand, category C/D drugs cannot be considered a priority in public procurement planning and, in case of limited resources, may be temporarily excluded from the formulary lists in favor of critically important drugs.

For an in-depth interpretation of the results of the ABC/VED analysis of antibiotics registered in Colombia, it is advisable to compare them with similar studies conducted in countries with similar economic situations or similar models of regulatory policies in the field of pharmaceutical provision [31]. Such a comparison allows us to assess the compliance of the national pharmaceutical market with modern global approaches to the rational use of antibiotics.

In a study conducted in South Asia, most antibiotics classified as category A according to the ABC analysis also fell into the Essential (E) or Vital (V) groups according to the VED criteria. Thus, ceftriaxone and meropenem, which are used for severe infections in hospital settings, were classified as A/V [32].

Similar results were obtained in North Africa, where parenteral β-lactams (ceftriaxone, ampicillin/sulbactam) were also classified as critical areas, and drugs with low procurement volumes, such as nitrofurantoin or clindamycin, were classified as C/D [33].

Another study confirmed that amoxicillin/clavulanate and azithromycin occupy a significant share of consumption in outpatient practice and fall into category A/E, which coincides with the data obtained in our analysis [28, 34].

In most international studies, a similar trend towards the dominance of broad-spectrum antibiotics from the Access (basic antibiotics) and Watch (controlled use) groups (according to the WHO AWaRe classification) in critical categories A/V and A/E is observed. This indicates a global pattern: the most resources are spent on those drugs that are therapeutically effective, clinically significant, and frequently used for the most common infections.

Also common is the low share of spending on antimicrobial medicines from the C/D category, which confirms their limited role in the structure of antibacterial treatment. At the same time, in some countries C/D drugs are generally excluded from the nomenclature of state financing.

In Colombia, the average price of azithromycin packaging (500 mg, 3 tablets) is approximately 7 USD, which is lower than the average price level in the USA (from 10 to 20 USD). For parenteral drugs, such as ceftriaxone, prices in Colombia are comparable or slightly lower compared to EU countries, which is partly explained by the prevalence of generic forms and lower pharmacy markups.

Compared to EU markets, Colombia has a high level of imports and a significant presence of drugs from Turkey, India, Slovakia, Poland and Italy. This ensures the availability of most of the international generic names recommended by WHO, but often only 1-2 trade names per active substance, which limits competition.

Thus: the comparative analysis confirms the compliance of the Colombian pharmaceutical market with global trends in the classification of antibiotics by cost and importance. Ceftriaxone, amoxicillin/clavulanate and azithromycin occupy critical positions in all studies, regardless of the country. The cost of most antibiotics in Colombia is competitive, but the representation by brand is limited. The results can be used to further harmonize the formulary policy with international approaches and to optimize public supply.

The ABC/VED analysis of antimicrobial medicines for adults registered in Colombia allowed to identify priority areas for optimizing antibiotic therapy, taking into account international recommendations, cost-effectiveness and the current market situation. The results obtained are of great importance for the formation of local formularies, justification of state procurement and strategic management of drug supply.

The conducted study allowed to formulate substantiated approaches to increasing the effectiveness and safety of antibiotic therapy for adult patients by integrating economic and clinical factors. The established patterns of distribution of drugs by cost categories and clinical significance indicate the need for a comprehensive review of policies on formulary selection, procurement financing and logistical support of antibacterial agents.

Particular attention should be paid to priority groups of antimicrobial medicines, which are both high cost and strategic importance for the treatment of severe infections. These drugs ensure the preservation of patients' lives and the prevention of complications. At the same time, drugs with limited clinical feasibility, which consume insignificant resources, may be subject to optimization in terms of procurement volumes and inclusion in the nomenclature.

Taking into account international recommendations, in particular WHO provisions on the classification of antibiotics, the main strategic directions for optimizing antibiotic therapy have been identified, which are presented in Figure 4.

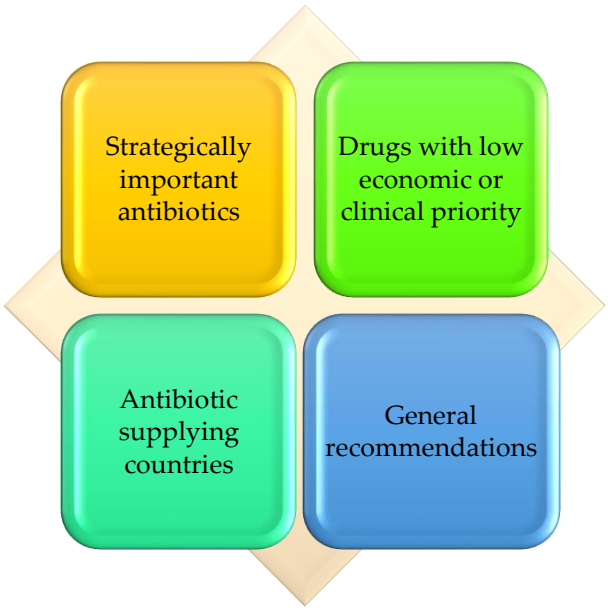

Figure 4. Priority areas for optimizing antibiotic therapy taking into account international recommendations

The following were included in the group of strategically important drugs that combine high clinical significance and a significant share of costs:

• Ceftriaxone (category A/V) – parenteral β-lactam, vital for severe infections (sepsis, meningitis, pneumonia);

• Amoxicillin/Clavulanic acid (A/E) – a broad-spectrum drug recommended in international first-line protocols for diseases of the respiratory tract, ENT organs, and urinary system;

• Azithromycin (A/E) – a macrolide for outpatient treatment of infections with high prevalence, in particular in patients with allergies to β-lactams.

These international non-proprietary names should be a priority when planning public procurement, forming basic formulas, and ensuring a guaranteed list of drugs.

Drugs with a relatively low share of costs (category C) and limited clinical use (category D) include:

• Clindamycin, Nitrofurantoin, Sulfamethoxazole/Trimethoprim (category C/D) – used in narrow clinical cases or have safety limitations;

• Metronidazole (C/E) – despite its frequent use in anaerobic infections, it occupies a small share of costs and has a limited need for centralized procurement.

These drugs do not require priority funding, but can remain in the formularies as reserve or specialized drugs.

The analysis of registered drugs showed that the main suppliers of antibiotics to the Colombian pharmaceutical market are:

• Turkey – a wide range of generic antibiotics, distinguished by their affordable price;

• India – a significant number of basic segment drugs, including aminoglycosides, penicillins and fluoroquinolones;

• Slovakia, Poland, Germany, Italy – European Union countries that supply both generics and original brands;

• USA and Canada – mainly injectable drugs and proprietary forms, represented in a limited way due to high cost.

General recommendations include: the results of the study can be used as a practical tool for making management decisions in the Colombian health system; the focus of public policy should be on ensuring a stable supply of drugs in categories A/V and A/E; low-priority antibiotics should be included in the formularies only when clinically appropriate and when there are appropriate indications.

Despite the comprehensive nature of the analysis, the results of the study require careful interpretation due to a number of methodological and informational limitations. First of all, it should be noted that the cost of antibacterial drugs was estimated based on the retail prices of only one trade name for each international non-proprietary name. Although this approach allows for a general idea of the level of costs, it does not take into account price variability within a single drug, which is especially relevant when there are several generic or original forms on the market.

In addition, the study did not include data on wholesale purchase prices or the terms of contracts concluded between distributors, government agencies or private medical institutions. Since wholesale prices, especially in the case of centralized purchases in large volumes, can differ significantly from retail prices, the lack of this information limits the accuracy of assessing the real economic burden on the health care system.

It should be noted separately that there is a lack of open data on the actual volume of antibiotic consumption among the adult population of Colombia. This makes it impossible to build a full-fledged ABC analysis model taking into account the total cost of drugs for the period (as the product of the average price and the number of packages consumed). The availability of such information would not only increase the accuracy of the analysis, but also ensure its connection to real epidemiological data.

The above limitations do not reduce the value of the results obtained, but emphasize the need for further research involving more complete information on consumption, the structure of contract purchases and competition between trade names within one international non-proprietary name.

The analysis has significant applied value for the formation of a sound policy in the field of pharmaceutical provision. Its results can be used at the level of state programs, medical institutions, pharmacies, in particular in three key areas.

First, the results of the ABC/VED analysis can be used as a basis for compiling local drug formularies in primary and secondary healthcare institutions, especially in patients with pleurisy, pleural empyema, tuberculosis and chronic infections. Identification of drugs with the highest clinical and economic significance allows for priority inclusion in the formularies of first-line drugs for the treatment of infections in adults, while avoiding duplication of drugs or the inclusion of drugs with low clinical potential. This contributes to the harmonization of the internal policy of medical institutions with the international recommendations of the World Health Organization and the AWaRe classification (Access, Watch, Reserve).

Secondly, the constructed ABC/VED matrix can become a tool for optimizing the process of public procurement and logistics of medicines. Identification of drugs that form the main costs and are clinically critical (zones A/V and A/E) allows you to focus financial resources on truly important items. At the same time, drugs with low costs and secondary clinical significance (category C/D) can be removed from the nomenclature of centralized supply or purchased in reduced volumes. This approach increases the efficiency of budget planning, helps reduce costs and reduces the risks of shortages of drugs of strategic importance.

Thirdly, the applied analysis is universal and can be adapted to the pharmaceutical systems of other countries, in particular those that are in the process of reform. A similar approach can be used to analyze pharmaceutical supply in countries with economies in transition, in conditions of limited availability of statistical data, as well as to modernize internal control systems for the circulation of antibacterial agents. Such a tool is especially relevant for participation in international technical assistance programs, WHO initiatives to combat antibiotic resistance and harmonization with European Union policies.

Therefore, the results of the study can be effectively integrated into pharmaceutical management mechanisms at different levels of the health care system, contributing to strengthening the evidence base, economic feasibility, effectiveness and quality of antibiotic therapy.

4. CONCLUSION

The conducted study allowed for a comprehensive ABC/VED analysis of antibiotics registered in Colombia, with an emphasis on international non-proprietary names recommended by leading clinical protocols and WHO lists. The analysis revealed that the highest share of costs and clinical significance are drugs from the β-lactam (ceftriaxone, amoxicillin/clavulanate) and macrolide (azithromycin) groups, which should be considered strategic for guaranteed supply, government procurement, and patient care.

Other drugs belonging to categories B/E and C/D have limited clinical or economic value and may be reviewed in terms of inclusion in formularies and procurement lists. The analysis also confirmed the dominance of manufacturers from Turkey, India, and the European Union in the structure of antibiotic supply to the Colombian pharmaceutical market, in the absence of domestic drugs.

Despite the existing limitations, the results of the study have high practical value for optimizing pharmaceutical supply, rational formation of local formularies, increasing the efficiency of procurement and management of drug stocks. The proposed comprehensive assessment can also be adapted for analyzing the pharmaceutical market in other countries of the world, especially in the context of reforming healthcare systems, limited budgets and the need

to implement modern tools and digital medical technologies. Thus, a combined approach based on ABC/VED analysis, taking into account the international evidence base, is an effective tool for ensuring the availability of vital antibiotics for patients with pleurisy, pleural empyema, tuberculosis, chronic infections and improving the quality of medical and pharmaceutical management at the national level.

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Authors' contributions
Concept development: Viktoriia Shapovalova. Manuscript preparation: Oleksandr Nevzghoda, Valerii Shapovalov, Olena Lavoshnyk. Review and final version of the manuscript: Valentyn Shapovalov, Alina Osyntseva. All authors contributed to data analysis, drafting, and revising of the paper and agreed to be responsible for all the aspects of this work.

CONFLICT OF INTEREST

The authors have approved the article for publication and declare that there is no conflict or potential conflict of interest.

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